Diffusion barriers in Sc/Si multilayers

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Periodic multilayers (MLs) of Sc and Si have high reflectivity in the soft X-ray range of 35-50 nm. Although theoretical prediction gives values up to 70 %, experimental reflectivities of Sc/Si MLs do not exceed 50 % yet. This is due to phase instability of the Sc-Si binary material system resulting in an interaction and intermixing of layers both in as-deposited state and after annealing.

The purpose of this work is to elevate the structure stability and to improve optical characteristics of Sc/Si MLs by application of diffusion barriers.

All multilayers with periods 20-35 nm were deposited by DC magnetron sputtering. Their structure and the phase composition were studied by methods of cross-sectional transmission electron microscopy (TEM) and small-angle X-ray diffraction.

The structure of as-deposited Sc/Si coatings was found to represent alternating poly-Sc and amorphous-Si layers separated by amorphous interlayers (~3 nm thick) having the composition and the density which were close to the scandium silicide, ScSi. During heating at temperatures 210-250 °C a symmetric increase of the interlayer thickness with simultaneous amorphization of poly-Sc layers take place. Further raising of temperature leads to a consumption of Si by Sc-based layers and formation of polycrystal Sc_3Si_5. Results of isothermal annealing show that growth of interlayer thickness follows to a parabolic dependence on time ($x \sim \tau^{0.5}$). Interdiffusion coefficients are estimated to be $\sim 10^{-18}$ and $\sim 10^{-16}$ cm^2/s at 210 °C and 250 °C correspondingly.

To suppress the process of the diffusion degradation we introduced diffusion barrier layers in Sc/Si multilayers. As a material for barrier layers we chose tungsten because it doesn’t react with scandium, has acceptable optical refraction index and has high enough melting temperature. During deposition of a multilayer, W-layers were applied between Sc- and Si-layers to form diffusion barriers of 0.8-1.4 nm thick successively. Absence of intermixed interlayers at both Sc-Si interfaces is clear visible in the TEM images for all multilayers in as-deposited state. Comparative annealing of Sc/Si and W/Sc/W/Si MLs demonstrates remarkable structure stability of the latter within the temperature range of 200-400 °C. Interdiffusion coefficients in multilayers with W barrier layers of 0.8 nm and without W distinguish at least 3 order of magnitude at 250 °C.

Both types of multilayers show close reflectivities in the soft X-ray region at normal incidence: ~25 % for W/Sc/W/Si ML with W-layers of 0.8 nm thick and ~30 % for Sc/Si ML at λ=41.5 nm. Besides the introduction of W barrier layers allows to raise 100-150 °C up the temperature range of Sc/Si ML applicability.

Further optimization of the barrier structure to improve optical characteristics of Sc/Si multilayers is under progress.

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